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Specification

Title of the Invention

Optical Recording Medium, Manufacturing Method for Optical Recording Medium, and Reproducing Method for Optical Recording Medium

Technical Field

The present invention relates to an optical recording medium, particularly, an optical disk which is shaped like a circular plate and is used to reproduce information.

Background Art

As a conventional optical recording medium, for example, there is an optical disk, such as a CD-ROM and a DVD-ROM. In such an optical disk, an uneven row of pits is formed on a transparent substrate which is made of polycarbonate or the like. On the substrate, a metal reflection film is formed which is made of Al or the like. From the side of the surface opposite to the surface on which this metal reflection film is formed, a beam of light is applied to the metal reflection film which is an information recording surface. Thereby, information is reproduced.

Such an optical recording medium has been widely used in which information is recorded and reproduced by applying a beam of light. Thus, expectations have become greater of

ATTACHMENT B

heightening its recording density from now on. In recent years, a variety of optical disks have been developed which can reproduce large-capacity audio-visual data or digital data. For example, research and development for a high-density ROM optical disk is now going on, in which the density of an optical disk which has a diameter of 12 centimeters is expected to become higher to a storage capacity of 23.3 to 30 gigabits.

On the other hand, a DVD ROM recording medium is provided with a security technique, specifically, the technique of preventing someone from illicitly using and copying recorded information or from doing such an act. As that security technique, a BCA (or burst cutting area) area is provided where medium identification information which is used to identify each recording medium individually is overwritten in a bar-code pattern. In this BCA area, when an optical recording medium is manufactured, medium identification information which differs for each optical recording medium is recorded, and if necessary, a key of cryptograph or a key of decoding is recorded.

For example, Japanese Patent Laid-Open No. 10-233019 specification discloses that a metal reflection film of an optical disk on which a row of pits is formed as main data is partially removed by a laser trimming, and modulated data is recorded individually. Thus, medium identification information is recorded which is used to protect against

illicitly using and copying, or such an act.

However, in order to heighten the above described density, the pitch between tracks has to be narrowed, or the shortest pit of a row of pits needs to be shortened. Besides, with respect to a high-density optical disk, 23.3 GB or more data is recorded on a 12cm-diameter optical disk. Therefore, it has been found out that if on a substrate used for such an optical disk, a metal reflection film is formed which is made of an Al alloy material having a film thickness of 50 to 70nm so that it can be used in a DVD ROM optical disk, that deteriorates the quality of a reproduced signal.

This is because a metal reflection film seems to be difficult to form at the bottom of a minute pit about 0.2 μm long. Thus, the shorter a pit becomes, the deeper and the smaller it tends to be. Accordingly, as a metal reflection film for the above described high-density ROM optical disk, a metal reflection film which is used in a DVD ROM optical disk could not be used as it is.

In addition, when a DVD ROM optical disk is manufactured, medium identification information is recorded, using a medium-identification-information recording apparatus which is provided with a YAG (yttrium aluminum garnet) laser. However, even if the medium identification information is recorded in a bar-code pattern using this medium-identification-information recording apparatus, on an area where pits are not formed in a high-density ROM optical

disk or on a row of pits which is recorded at a track pitch of 0.74 μm which is the same as in the DVD ROM optical disk, then the pattern could not be formed. Or, the reproduction noise of the medium identification information became louder, and thereby, an adequate defocus margin could not be secured.

This is because in a high-density ROM optical disk, a metal reflection film is thinner than that of a DVD ROM optical disk. Or, the material of a metal reflection film in use is different, and thus, the heat capacity necessary until the metal reflection film reaches its melting point is largely different. Accordingly, a conventional medium-identification-information recording apparatus provided with a YAG could not be used as it is when a high-density ROM optical disk is manufactured.

Disclosure of the Invention

It is an object of the present invention to provide an optical recording medium in which data can be recorded more densely than in a DVD ROM optical disk, and using a conventional medium-identification-information recording apparatus, medium identification information can be recorded so that an adequate defocus margin can be secured.

An optical recording medium according to an aspect of the present invention: which includes a main-information area in which a metal reflection film is formed on a substrate where a row of pits is formed as main data, and a sub-information

area in which medium identification information is recorded which is used to identify the optical recording medium individually by removing the metal reflection film partially and forming a plurality of reflection-film removed areas; and in which information is reproduced by irradiating the metal reflection film with a beam of light, where in the sub-information area, a row of pits or a groove is formed on the substrate, and the track pitch of the row of pits or the groove is 0.24 μm or wider and 0.45 μm or narrower.

In this optical recording medium, a row of pits or a groove is formed in the sub-information area on the substrate, and the track pitch of the row of pits or the groove is set at 0.24 μm or wider and 0.45 μm or narrower. Therefore, using a beam of light for reproduction having a shorter wavelength and an optical system having a higher numerical aperture, data can be recorded at a higher density than in a DVD ROM optical disk. In addition, even though the thermal conductivity or melting point which is the intrinsic value of the metal reflection film is different, using a conventional medium-identification-information recording apparatus, medium identification information can be recorded so that an adequate defocus margin can be secured.

A manufacturing method for an optical recording medium according to another aspect of the present invention, including: a first step of preparing a substrate on which a row of pits is formed as main data in a main-information

area, and a row of pits or a groove whose track pitch is 0.24 μm or wider and 0.45 μm or narrower is formed in a sub-information area; a second step of forming a metal reflection film on the substrate; a third step of forming a resin layer on the metal reflection film; and a fourth step of recording medium identification information which is used to identify the optical recording medium individually by partially removing the metal reflection film in the sub-information area and forming a plurality of reflection-film removed areas.

By this manufacturing method for an optical recording medium, the row of pits or the groove is formed in the sub-information area on the substrate, and the track pitch of the row of pits or the groove is set at 0.24 μm or wider and 0.45 μm or narrower. Therefore, using a beam of light for reproduction having a shorter wavelength and an optical system having a higher numerical aperture, data can be recorded at a higher density than in a DVD ROM optical disk. In addition, even though the thermal conductivity or melting point which is the intrinsic value of the metal reflection film is different, using a conventional medium-identification-information recording apparatus, medium identification information can be recorded so that an adequate defocus margin can be secured.

A reproducing method for an optical recording medium according to still another aspect of the present invention, in which: the optical recording medium includes a

main-information area in which a metal reflection film is formed on a substrate where a row of pits is formed as main data, and a sub-information area in which a row of pits or a groove whose track pitch is 0.24 μm or wider and 0.45 μm or narrower is formed on the substrate, and medium identification information is recorded which is used to identify the optical recording medium individually by removing the metal reflection film partially and forming a plurality of reflection-film removed areas; and information is reproduced by irradiating the metal reflection film of the optical recording medium with a beam of light.

By this reproducing method for an optical recording medium, information is reproduced by applying a beam of light to the metal reflection film of the optical recording medium which includes a sub-information area where the row of pits or the groove is formed in the sub-information area on the substrate and the track pitch of the row of pits or the groove is set at 0.24 μm or wider and 0.45 μm or narrower. Therefore, using a beam of light for reproduction having a shorter wavelength and an optical system having a higher numerical aperture, a good-quality signal can be obtained by reproducing the data which has been recorded at a higher density than in a DVD ROM optical disk. In addition, even though the thermal conductivity or melting point which is the intrinsic value of the metal reflection film is different, using a conventional medium-identification-information recording apparatus, the

medium identification information which has been recorded at an adequate defocus margin can be steadily reproduced.

Brief Description of the Drawings

Fig. 1 is a graphical representation, showing a measurement result of the jitter value which corresponds to the depth of a pit.

Fig. 2 is a graphical representation, showing a measurement result of the jitter value which corresponds to the film thickness of a metal reflection film which is made of an AgPdCu alloy.

Fig. 3 is a graphical representation, showing a measurement result of the jitter value which corresponds to the film thickness of a metal reflection film which is made of an Al alloy.

Fig. 4 is a sectional view of an optical disk in which a metal reflection film which is made of an AgPdCu alloy and has a film thickness of 100nm is formed on a substrate where pits are formed.

Fig. 5 is a graphical representation, showing a measurement result of the reflectance ratio which corresponds to the film thickness of a metal reflection film which is made of an AgPdCu alloy.

Fig. 6 is a graphical representation, showing a measurement result of the reflectance ratio which corresponds to the film thickness of a metal reflection film which is

made of an Al alloy.

Fig. 7 is a top view of an optical disk, showing an example of its main-information area and sub-information area.

Fig. 8 is a block diagram, showing the configuration of a medium-identification-information recording apparatus which records medium identification information in a BCA area.

Fig. 9 is a sectional view of an optical disk in which a metal reflection film is formed on a substrate where pits are formed, and in addition, a resin layer is formed on the metal reflection film.

Fig. 10 is a graphical representation, showing a measurement result of the defocus margin of a BCA recording power which corresponds to the track pitch of a row of pits which is formed in an optical disk that includes a 50nm metal reflection film which is made of an AgPdCu alloy.

Fig. 11 is a graphical representation, showing a measurement result of the defocus margin of a BCA recording power which corresponds to the track pitch of a row of pits which is formed in an optical disk that includes an Al reflection film whose film thickness is 30nm.

Best Mode for Implementing the Invention

Hereinafter, a ROM optical disk will be described as an example of the optical disk according to an embodiment

of the present invention. Herein, an optical recording medium which is applied according to the present invention is not limited especially to this example. The present invention can also be applied to various optical recording mediums whose information recording layer has, for example, a minute unevenness, such as an optical magnetic disk and a phase-change disk.

The ROM optical disk includes: a main-information area in which a metal reflection film is formed on a substrate where an uneven row of pits is formed as main data; and a sub-information area in which medium identification information is recorded which is used to identify the optical disk individually by removing the metal reflection film partially and forming a plurality of reflection-film removed areas. In this optical disk, information is reproduced by irradiating the metal reflection film with a beam of light.

Generally, in order to heighten the density of a ROM optical disk, the pitch between tracks has to be narrowed, and the shortest pit length (or the shortest mark length) needs to be extremely shortened. However, if the track pitch becomes too narrow, cross talk becomes greater in an RF-signal characteristic. This hinders securing an adequate system margin. If the shortest pit length becomes too short, then the resolution of a reproduced signal lowers, thereby worsening the jitter value of the reproduced signal.

Therefore, an examination is repeatedly made of the

most suitable track pitch, using an information reproducing apparatus in which a wavelength λ of a light source of a beam of light for reproduction is 405nm and a numerical aperture NA of an objective lens is 0.85. As the result of such an examination, the following measurement result is obtained. This presents the fact that if a track pitch is 0.24 μm or wider, a cross-talk signal can be practically neglected, compared with a main signal.

Track Pitch (μm)	Jitter Value (%)
0. 20	7. 6
0. 22	7. 0
0. 24	6. 5
0. 26	5. 6
0. 28	5. 4

In addition, the most suitable shortest pit length is examined, using the above described information reproducing apparatus. As a result of the study of a resolution necessary for obtaining a desirable reproduction signal, a measurement result is obtained as follows. It has turned out that if the length of the shortest pit is 0.12 μm or longer, the resolution of a reproduced signal can be adequately secured.

Shortest-Pit Length (μm)	Jitter Value (%)
0. 10	8. 2
0. 11	6. 8
0. 12	6. 5
0. 13	5. 4
0. 14	5. 3

Herein, in consideration of various margins of an optical disk or a drive, a jitter value which shows characteristics of an optical disk needs to be 6.5% or below.

Herein, information on a 12cm-diameter optical disk is reproduced, using the information reproducing apparatus. In order to set the storage capacity of the optical disk to 23.3GB or above, a relational expression (shortest pit length) $\times$ (track pitch) $\leqq 0.0512\,\mu m^2$ has to be satisfied. For example, if the recording capacity is 23.3GB and the shortest pit length is $0.12\,\mu m$, the upper limit of the track pitch is about $0.43\,\mu m$. In the same way, if the recording capacity is 23.3GB and the shortest pit length is $0.24\,\mu m$, the upper limit of the track pitch is about $0.21\,\mu m$.

Next, a manufacturing method will be described of a 12cm-diameter optical disk which has a recording capacity of 23.3GB or above. As described above, in order to create a 12cm-diameter optical disk which has a recording capacity of 23.3GB or above, a substrate has to be used whose track pitch is $0.24\,\mu m$ or wider and $0.43\,\mu m$ or narrower, and its shortest pit length is $0.12\,\mu m$ or longer and $0.21\,\mu m$ or shorter.

For example, in order to create a 12cm-diameter optical disk which has a recording capacity of 25GB, first, a substrate is prepared where a row of pits is formed which has a shortest pit length of $0.149\,\mu m$ and a track pitch of $0.32\,\mu m$. As this substrate, for example, a substrate made of polycarbonate can be used which is created by an injection molding machine.

Next, a metal reflection film is formed on this substrate, using a film formation apparatus. As the film formation apparatus, the one which can form a metal reflection film uniformly, such as a magnetron sputtering apparatus and a vapor depositing apparatus, can be used. For example, using a magnetron sputtering apparatus, the time for film formation can be varied, thereby controlling the film thickness of the metal reflection film. Herein, the material, film thickness, or the like, of the metal reflection film will be described later.

Next, the optical disk is placed on a spin coater, with the metal reflection film kept up. Then, a resin to be hardened by ultraviolet rays is dripped, and on top of it, an 88 μ m-thick transparent sheet which is made of polycarbonate is placed. In this state, the ultraviolet-ray hardened resin is irradiated with ultraviolet rays while the optical disk is being rotated by the spin coater. At this time, the rotational speed of the spin coater is controlled, so that the thickness of the ultraviolet-ray hardened resin after it has hardened becomes 12 μ m. As a result, a transparent resin layer which has a film thickness of 100 μ m is formed on the metal reflection film. For example, an acrylic resin can be used as this ultraviolet-ray hardened resin.

In such a way as described above, the metal reflection film was formed on the substrate where the row of pits was formed which had a shortest pit length of 0.149 μ m and a track

pitch of 0.32 μm. On top of it, the resin layer which had a film thickness of 100 μm is formed, and consequently, an optical disk is manufactured.

Next, with respect to the optical disk which was manufactured as described above, a study was made of the depth of a pit which corresponds to the quality of a reproduced signal, the material and film thickness of the metal reflection film, and the like. Specifically, the manufactured optical disk was set in the above described information reproducing apparatus. Then, this information reproducing apparatus allowed a beam of light to be incident upon the metal reflection film through the 100 μm-thick resin layer. Thereby, a reproduced signal was obtained from the optical disk, and then, it was assessed.

First, an examination was made how much the quality of a reproduced signal depended upon the depth of a pit. In the optical disk which was manufactured as described above, jitter values were measured which showed the dispersion of reproduced signals when the depth of a pit varied. Fig. 1 is a graphical representation, showing a measurement result of the value of a jitter which corresponds to the depth of a pit. Its horizontal axis is the depth (nm) of a pit and the vertical axis is the value (%) of a jitter. In Fig. 1, as the metal reflection film, the one was used which was made of an Al alloy with a purity of 99wt% and had a film thickness of 25nm. However, even when the one which was made

of an Ag98Pd1Cu1(wt%) (hereinafter, referred to as the AgPdCu alloy), the same result as the following was obtained.

Generally, in order to secure an adequate system margin, the value of a jitter has to be 6.5% or below. In Fig. 1, it could be seen that if the depth of a pit is set to 44nm or above and 88nm or below, the value of a jitter would be 6.5% or lower. Herein, a refractive index n of the created resin layer was 1.53, and a wavelength λ of the beam of light was 405nm. Therefore, taking the above described measurement result into account, you could see that a depth D of a pit at which a desirable reproduction signal would be obtained is $\lambda/(6\times n)$ or above, and $\lambda/(3\times n)$ or below.

This seems to be for the following reason. Specifically, the depth of a pit affects the amplitude of a reproduced signal, and in an optical calculation, when the depth of a pit is $\lambda/(4\times n)$, the amplitude becomes maximum. If the refractive index n of the resin layer is 1.53 and the wavelength λ of the beam of light is 405nm, it becomes maximum when the pit depth is about 66nm. But, even if the amplitude becomes a little smaller, the jitter value of a reproduced signal is almost unchanged. However, if the pit depth is below $\lambda/(6\times n)$, or if the pit depth is above $\lambda/(3\times n)$, then an adequate signal-to-noise ratio (hereinafter, referred to as the S/N ratio) cannot be obtained, thereby worsening the jitter value of the reproduced signal.

Next, a study was made of a suitable film thickness

of a metal reflection film. First, a substrate was prepared in which the depth of a pit is $\lambda/(4\times n)$. As the metal reflection film, two kinds were used which were a metal reflection film which was made of the AgPdCu alloy and a metal reflection film which was made of an Al alloy with a purity of 99wt%. Then, the value of a jitter was measured when their film thickness was varied. Fig. 2 is a graphical representation, showing a measurement result of the jitter value which corresponds to the film thickness of the metal reflection film which is made of the AgPdCu alloy. Fig. 3 is a graphical representation, showing a measurement result of the jitter value which corresponds to the film thickness of the metal reflection film which is made of the Al alloy. In each figure, the horizontal axis is the film thickness (nm) of the metal reflection film, and the vertical axis is the value (%) of a jitter.

As can be seen in Fig. 2, in the case of the metal reflection film of the AgPdCu alloy, if its film thickness was 25nm or above and 75nm or below, the value of a jitter became 6.5% or lower. On the other hand, as shown in Fig. 3, in the case of the metal reflection film of the Al alloy, if its film thickness was 15nm or above and 40nm or below, the value of a jitter became 6.5% or lower. Herein, the material of a metal reflection film is not limited especially to those in the examples. Another material may also be used, as long as it has a high reflectance ratio and can be uniformly formed

on a substrate by a film formation apparatus. In addition, in order to enhance its corrosion resistance, a rare-earth metallic element such as Nd, or a transition metallic element such as Ti and Cr, may also be added a little to an Ag or Al reflection-film material.

Next, the reflectance ratio of a metal reflection film was examined. The thinner a metal reflection film becomes, the smaller the quantity of reflected light will be. Then, when the quantity of reflected light becomes smaller, in proportion to that, a medium noise also lowers. This keeps the S/N ratio unchanged. On the other hand, a system noise or a laser noise does not depend upon the quantity of reflected light. If the system noise or the laser noise is far lower than the medium noise so that it can be neglected, then it will not affect the quality of a reproduced signal, even though the quantity of reflected light becomes smaller.

However, if the quantity of reflected light becomes smaller, and the system noise or the laser noise reaches the same level as the medium noise, then the quality of a reproduced signal will deteriorate when the quantity of reflected light decreases. Besides, if the metal reflection film is made of a different material even though it has the same film thickness, that will change its reflectance ratio, and thereby, will change the film thickness at which the signal quality worsens. In addition, if the metal reflection film becomes thicker, the reproduced signal will become worse.

For example, in a magnetron sputtering apparatus, the metallic atoms on a target which have been sputtered by Ar ions come flying onto a substrate, so that a metal reflection film is formed. The size of these metallic atoms also depends upon the structure of a film formation apparatus, or the conditions of film formation. But such a film tends to be difficult to form at the bottom of the shortest pit.

Fig. 4 is a sectional view of an optical disk in which a metal reflection film which is made of an AgPdCu alloy and has a film thickness of 100nm is formed on a substrate where pits are formed. As shown in Fig. 4, a shortest pit 11 and a long pit 12 which is longer than the shortest pit 11 are formed on a substrate 1. In this case, at the bottom of the shortest pit 11, a metal reflection film 2 is more difficult to form than at the bottom of the long pit 12. Therefore, the shortest pit 11 after the metal reflection film 2 has been formed becomes smaller, and at the same time, deeper than it was on the substrate 1.

If you anticipate this phenomenon, and thus, make a recording power greater so that the shortest pit 11 can be greater, then the signal quality of the shortest pit 11 will improve. However, when the recording power becomes greater, the long pit 12 will be wider. This makes the cross talk greater which comes from adjacent tracks, thus worsening the value of a jitter. In consideration of the factors which can worsen the signal quality of both kinds of films, substrates

were formed which were suitable for the metal reflection films of an Al alloy and an AgPdCu alloy. As a result, the maximum film thickness of the Al-alloy metal reflection film at which the value of a jitter was prevented from worsening was 40 nm, and the maximum film thickness of the AgPdCu-alloy metal reflection film at which it was prevented from worsening was 70 nm.

Based on this study, a reflectance ratio was measured which corresponded to the film thickness of each of the AgPdCu-alloy metal reflection film which is shown in Fig. 2 and the Al-alloy metal reflection film which is shown in Fig. 3. Fig. 5 is a graphical representation, showing a measurement result of the reflectance ratio which corresponds to the film thickness of a metal reflection film which is made of an AgPdCu alloy. Fig. 6 is a graphical representation, showing a measurement result of the reflectance ratio which corresponds to the film thickness of a metal reflection film which is made of an Al alloy. In each figure, the horizontal axis is the film thickness (nm) of the metal reflection film, and the vertical axis is the reflectance ratio (%). Herein, the refractive index n of the resin layer which was used for measurement is 1.53, and the wavelength λ of the beam of light is 405nm.

As can be seen in Fig. 5, in the case of the AgPdCu-alloy metal reflection film, the reflectance ratio which corresponded to a film thickness of 25nm to 70nm at which

a desirable jitter value was obtained was 35% to 70%. In the case of the Al-alloy metal reflection film in Fig. 6, the reflectance ratio which corresponded to a film thickness of 15nm to 40nm at which a desirable jitter value was obtained was 35% to 70%. As a result, for each film, the reflectance ratio of the metal reflection film at which the quality of a reproduced signal could be guaranteed was 35% or higher and 70% or lower.

Next, in order to obtain a reproduction signal which has a desirable jitter value in such a way as described above, an uneven row of pits is formed as main data in a main-information area of an optical disk. A detailed description will be given of medium identification information which is formed in a sub-information area of the optical disk. Fig. 7 is a top view of an optical disk, showing an example of its main-information area and sub-information area.

In the example shown in Fig. 7, a main-information area 21 (which is a hatching part in the figure) is set in the outer circular part on the optical disk. In the ring-shaped part inside of the outer circular part, a BCA area 22 (which is the area between two circles shown by broken lines in the figure) is set which is a sub-information area. In the BCA area 22, medium identification information 23 is recorded in a bar-code pattern. A transparent resin layer of polycarbonate or the like is formed on the metal reflection film, and thereafter, the medium identification information

23 is recorded by irradiating, with a pulse laser (e.g., a YAG laser), the metal reflection film which lies at a depth of 0.1mm from the surface of the optical disk. At this time, the metal reflection film seems to melt, and then, accumulate at both boundary parts by surface tension. In this way, the metal reflection film is partially removed, and thus, several reflection-film removed areas are formed. This creates a BCA area where medium identification information is recorded which is used to identify the optical disk individually.

Next, the method of recording the medium identification information in the BCA area of an optical disk will be described in detail. Herein, in the following example, a method by which a record is made in the BCA area is described, with respect to a metal reflection film which is made of an Ag98Pd1Cu1(wt%), or a metal reflection film which is made of an Al99Cr1(wt%), as the metal reflection film. However, as long as the same effect can be obtained, the present invention can also be applied to other kinds of metal reflection films, a phase-change film, or an optical magnetic recording film.

Fig. 8 is a block diagram, showing the configuration of a medium-identification-information recording apparatus which records medium identification information in a BCA area. The medium-identification-information recording apparatus shown in Fig. 8 is a BCA-pattern recording apparatus which is used to create a BCA area in a DVD-ROM. It includes: a motor 101; a rotation control section 102; an optical pickup

103; a laser drive section 104; a waveform setting section 105; a BCA-signal generation section 106; a focus control section 107; a pre-amplifier 108; and a system control section 109.

The rotation control section 102 controls the rotation of the motor 101. The motor 101 rotates an optical disk 100 at a predetermined rotational speed. The BCA-signal generation section 106 creates a BCA signal by modulating medium identification information which is recorded in the optical disk 100. Based on the BCA signal, the waveform setting section 105 creates a laser modulation waveform. According to the laser modulation waveform, the laser drive section 104 drives a high-power laser inside of the optical pickup 103. The optical pickup 103 converges a beam of light emitted from the high-power laser, through its built-in optical system, upon the optical disk 100. The pre-amplifier 108 amplifies a reproduced signal which comes from the optical pickup 103, and then, outputs it to the focus control section 107. Using the amplified signal which comes from the pre-amplifier 108, the focus control section 107 controls an objective lens inside of the optical pickup 103, so that a beam of light can be converged on the metal reflection film of the optical disk 100. The system control section 109 systematically controls the operation of the rotation control section 102, the laser drive section 104, the waveform setting section 105, the BCA-signal generation section 106, and the focus

control section 107.

Next, a recording operation will be described of the medium-identification-information recording apparatus which is configured as described above. First, based on an instruction from the system control section 109, the rotation control section 102 drives the motor 101 to rotate the optical disk 100. The laser drive section 104 drives the high-power laser as a light source, and then, a beam of light which is emitted from the high-power laser is applied to the optical disk 100 from the optical pickup 103. At this time, the focus control section 107 executes focus control so that the beam of light which has been emitted from the high-power laser is converged on the metal reflection film of the optical disk 100.

Herein, the reflected light from the optical disk 100 is detected by a photo-detector inside of the optical pickup 103. Then, a reproduced signal is outputted as an electric signal from the photo-detector. This reproduced signal is amplified through the pre-amplifier 108 and is inputted in the focus control section 107. In response to the amplified signal, the focus control section 107 drives the objective lens of the optical pickup 103 and moves it slightly in a focus direction on the optical disk 100. Thus, it controls the optical pickup 103 so that the beam of light can be converged on the metal reflection film of the optical disk 100.

Next, the system control section 109 allows a position

detector (not shown) to detect the position of the optical pickup 103 in a tracking direction. Based on the detected positional information, it recognizes the optical pickup 103 to be located in a sub-information recording starting position. Next, the system control section 109 instructs the BCA-signal generation section 106 to generate a BCA signal. Then, the BCA signal is outputted from the waveform setting section 105, a BCA recording sequence starts, and the medium identification information is recorded in the BCA area.

In an optical disk where a 50nm-thick metal reflection film made of an AgPdCu alloy was formed, using the above described medium-identification-information recording apparatus, an attempt to record a BCA pattern (or a bar-code pattern) was made in a part where neither a row of pits nor a groove was formed. However, even if the output power of a laser was heightened, a reflection-film removed area in which the metal reflection film was removed could not be created.

This is because the melting point of Al is 660℃ while the melting point of Ag is 960℃. It takes a larger quantity of energy to melt the metal reflection film of an AgPdCu alloy. In addition, the thermal conductivity of Al is 237W/(m.K) while the thermal conductivity of Ag is 427℃. Therefore, a larger quantity of heat is diffused by the conduction of heat, even though the metal reflection film of an AgPdCu alloy is irradiated with a beam of light. Herein, in general,

the melting point of metal is lowered by mixing a different metal. However, in order to secure an adequate reflectance ratio and avoid corrosion, the wt% of Ag in the metal reflection film cannot be reduced to 97% or below.

Next, in the optical disk where the 50nm-thick metal reflection film made of an AgPdCu alloy was formed, a row of pits was formed at a track pitch of 0.24 μm which was used in the BCA area of a DVD-ROM, and a BCA pattern was recorded in that part. At this time, the BCA pattern could not be recorded at a predetermined width, and thus, information could not be reproduced. However, a part of the AgPdCu-alloy metal reflection film melts, and a small reflection-film removed part could be formed. This is because a metal reflection film tends to be difficult to form on an inclined surface of an uneven substrate, and thus, the film thickness of the metal reflection film in a pit inclined-surface part becomes thin locally and heat conduction is hindered.

Fig. 9 is a sectional view of an optical disk in which a metal reflection film is formed on a substrate where pits are formed, and in addition, a resin layer is formed on the metal reflection film. As shown in Fig. 9, the metal reflection film 2 is formed on the substrate 1 where the pit 12 is formed, and in addition, a resin layer 3 is formed on the metal reflection film 2. In this case, the film thickness of the metal reflection film 2 which is formed on an inclined-surface part 4 becomes thinner than the film thickness of the metal reflection film

2 which is formed on each of a pit-bottom part 5 and a flat-plate part 6. Thereby, the quantity of heat which is conducted around becomes smaller. Hence, the narrower the track pitch of a row of pits becomes and the larger the area of the inclined-surface part 4 becomes, the more easily heat will be conducted around. Besides, in the inclined-surface part 4, the volume per unit of the metal reflection film 2 is smaller than any other part. Therefore, its heat capacity necessary for reaching the melting point becomes smaller, and thus, it reaches the melting point with a lower irradiation power.

Based upon the above described knowledge, optical disks were prepared in which a 50nm-thick metal reflection film made of an AgPdCu alloy was formed on each substrate where a row of pits was formed at various track pitches. Then, a BCA pattern was recorded in each optical disk. Fig. 10 is a graphical representation, showing a measurement result of the defocus margin of a BCA recording power which corresponds to the track pitch of a row of pits which is formed in an optical disk that includes a 50nm metal reflection film which is made of an AgPdCu alloy. Its horizontal axis is the track pitch (μm) of a row of pits and the vertical axis is the defocus margin (%).

As shown in Fig. 10, in the area where a row of pits was formed at a track pitch of 0.54μm or below, a BCA pattern could be recorded, and medium identification information

could be recorded. On the other hand, in the area where a row of pits was formed at a track pitch of 0.54 μm or above, no defocus margin could be secured. Herein, the judgment that a BCA pattern was recorded, was made by setting and reproducing the created optical disks in an assessment machine. It was made based upon whether or not the medium identification information which was recorded in the BCA area could be accurately reproduced. As the assessment machine, a reproducing apparatus was used in which a beam of light for reproduction had a wavelength λ of 405 nm and an objective lens had a numerical aperture NA of 0.85.

Herein, if you take the mass production of optical disks into account, you have to consider a number of factors, such as the dispersion of the film thickness of a metal reflection film, and a variation in a BCA recording power. Therefore, a defocus margin of 20% or higher is required as its adequate level. In Fig. 10, the track pitch at which a defocus margin of 20% or higher is obtained is 0.24 μm or wider and 0.45 μm or narrower. Hence, if the track pitch of a row of pits which is recorded in the BCA area is 0.24 μm or wider and 0.45 μm or narrower, an adequate defocus margin can be secured, and medium identification information can be recorded. The presumable reason for this is described below.

Specifically, if the track pitch of a row of pits which is recorded in the BCA area is beyond 0.45 μm, the number

of pits per unit area becomes smaller, and thus, the area of the inclined-surface parts of pits also becomes smaller. This hinders heat conduction from being cut off adequately. Therefore, if the heat capacity which is absorbed by a metal reflection film varies according to the defocus, a BCA pattern whose noise is low cannot be recorded.

On the other hand, if the track pitch is narrower than 0.24 μm, a pit is too close to its adjacent pits. Therefore, the formation of a land part between pits becomes inadequate, and the angle of the inclined-surface part of a pit becomes narrower. Thereby, a metal reflection film becomes easier to form on the inclined-surface parts of such pits, and thus, the effect of cutting off heat conduction by the formation of pits is reduced. Herein, in Fig. 10, a BCA pattern could be recorded and reproduced up to the point where the track pitch was 0.22 μm, while a BCA pattern could not be recorded when the track pitch was narrower than 0.22 μm. Hence, in Fig. 10, a dotted line is an estimated line which corresponds to a track pitch of 0.22 μm or below.

In addition, Fig. 10 shows that in an optical disk where a 50nm-thick metal reflection film made of an AgPdCu alloy was formed, the defocus margin is dependent upon the track pitch. However, in an optical disk where a desirable jitter value was obtained, a metal reflection film which was made of Ag or an Ag alloy might also have a film thickness of 25nm or above and 70nm or below. In that case, if the

track pitch of a row of pits which was recorded in a BCA area was 0.24μm or wider and 0.45μm or narrower, a defocus margin could be obtained at the same level as described above.

Similarly, instead of a row of pits, the same experiment as described above was also conducted in an optical disk where a groove was formed. Even in the case of a groove, a metal reflection film tended to be difficult to form at the inclined-surface part of the groove, as was the case with a row of pits. Thus, if the track pitch of a groove which was recorded in a BCA area was 0.24μm or wider and 0.45μm or narrower, a defocus margin could be obtained at the same level as described above.

Therefore, in the case of an optical disk where a desirable jitter value was obtained, a metal reflection film which was made of Ag or an Ag alloy had a film thickness of 25nm or above and 70nm or below, if the track pitch of a row of pits or a groove which was recorded in a BCA part was 0.24μm or wider and 0.45μm or narrower, then a defocus margin could be adequately secured.

Next, an optical disk will be described whose metal reflection film was created by using a metal reflection film which was made of an Al99Cr1(wt%) (hereinafter, referred to as the Al reflection film). First, an optical disk was prepared where the Al reflection film having a film thickness of 30nm was formed. Using the above described medium-identification-information recording apparatus, an

attempt to record a BCA pattern was made in a part where neither a row of pits nor a groove was formed. In this case, a part could be formed in which the Al reflection film was removed, and in addition, the medium identification information which was recorded as the BCA pattern could also be reproduced. However, the Al reflection film was thinner than the one (i.e., 50 to 70nm) which was used in a DVD-ROM, and thus, an adequate defocus margin could not be obtained. In addition, in the optical disk where the Al reflection film with a film thickness of 30nm was formed, if a BCA pattern was recorded in the area where a row of pits was formed at the 0.74 μm track pitch which was used in the BCA area of the DVD-ROM, then the same result as described above was obtained.

Therefore, an optical disk was prepared where the Al reflection film with a film-thickness of 30nm was formed on a substrate where a row of pits was formed at various track pitches. Then, a BCA pattern was recorded. Fig. 11 is a graphical representation, showing a measurement result of the defocus margin of a BCA recording power which corresponds to the track pitch of a row of pits which is formed in an optical disk that includes an Al reflection film which has a film thickness of 30nm. Its horizontal axis is the track pitch (μm) of a row of pits, and the vertical axis is the defocus margin (%).

Even in the case of the Al reflection film, in the

same way as described above, a defocus margin of 20% or higher is required at the time of BCA recording. In Fig. 11, the track pitch at which a defocus margin of 20% or higher is obtained is 0.24 μm or wider and 0.45 μm or narrower. Hence, even in the optical disk where the Al reflection film with a thinner film thickness than that of a DVD-ROM is formed, if the track pitch of pits which is recorded in the BCA area is 0.24 μm or wider and 0.45 μm or narrower, an adequate defocus margin can be secured, and medium identification information can be recorded. The presumable reason for this is described below.

Specifically, if the track pitch of a row of pits which is recorded in the BCA area is beyond 0.45 μm, the heat capacity necessary for reaching the melting point becomes extremely small, because the Al reflection film is thin. Thereby, the edge part of a BCA pattern is not formed desirably, thus making louder the noise of a BCA reproduction signal.

On the other hand, if a row of pits is formed at a track pitch of 0.45 μm or narrower, the narrower the track pitch becomes, the more likely a pit is formed at the edge of a BCA pattern. Thus, the melted Al reflection film is kept from flowing at the part where a pit is formed. Hence, in the area where pits are formed at a narrower track pitch, the noise of a BCA pattern becomes lower. As a result, if a row of pits is formed at a track pitch of 0.45 μm or narrower, a BCA pattern which realizes an adequate defocus margin can

be recorded.

However, if the track pitch becomes narrower than 0.24 μm, the angle of the inclined surface of a pit which is formed becomes narrower. This weakens the force which prevents the Al reflection film from flowing, and thus, an adequate defocus margin cannot be obtained.

Therefore, if a row of pit is formed on a substrate at a track pitch of 0.24μm or wider and 0.45μm or narrower, the control of heat is easily conducted even in an Al reflection film which has a thin film thickness. Consequently, the Al reflection film could be removed almost completely, and thus, a desirable BCA pattern could be recorded.

Herein, Fig. 11 shows that in an optical disk where a 30nm-thick metal reflection film made of an Al99Cr1(wt%) was formed, the defocus margin is dependent upon the track pitch. However, in an optical disk where a desirable jitter value was obtained, a metal reflection film which was made of Al or an Al alloy might also have a film thickness of 15nm or above and 40nm or below. In that case, if the track pitch of a row of pits which was recorded in a BCA area was 0.24μm or wider and 0.45μm or narrower, a defocus margin could be obtained at the same level as described above.

Similarly, instead of a row of pits, the same experiment as described above was also conducted in an optical disk where a groove was formed. Even in the case of a groove, the same effect could be produced. Thus, if the track pitch

of a groove which was recorded in a BCA area was 0.24μm or wider and 0.45μm or narrower, a defocus margin could be obtained at the same level.

Next, a multi-layer optical disk will be described which is a multi-layer optical recording medium which is formed by laminating a plurality of metal reflection films as information recording layers. For example, on a first polycarbonate substrate having a thickness of 1.1mm where a row of pits is formed, a first metal reflection film which is made of Al and has a film thickness of 45nm is formed, using the above described magnetron sputtering apparatus. Onto it, a second polycarbonate substrate having a thickness of 15μm where pits are formed is glued, so that its side where those pits are not formed comes into contact. As the adhesive, for example, a resin to be hardened by light or the like is used which is strong in adhesive bonding. Then, on the second polycarbonate substrate which has been glued in such a way as described above, a metal reflection film is formed which is made of AgPdCu and has a film thickness of 28nm. On top of it, a transparent resin layer is glued which has a thickness of 70μm. As the adhesive, for example, a pressure-sensitive adhesive sheet or the like is used.

Even in the double-layer optical disk which was created in such a way as described above, if the track pitch of a row of pits which was recorded in a BCA area is 0.24μm or wider and 0.45μm or narrower, a focus was adjusted at the

time of a BCA recording, and thereby, a BCA pattern could be recorded in both layers. Hence, a defocus margin could be obtained at the same level as described above.

Herein, the method of creating a multi-layer optical disk is not limited especially to the above described example. Before a transparent resin layer is glued, a plurality of substrates may also be formed, so that a multi-layer optical disk can be obtained. In this case, even if an optical disk is layered, a focus is adjusted at the time of a BCA recording, and thereby, a BCA pattern can be recorded in a desired layer. In addition, when a transparent resin layer and a polycarbonate substrate are glued, a light-hardened resin and a pressure-sensitive adhesive sheet are used. But instead of them, an adhesive and transparent medium, such as a dry photo-polymer, may also be used. Or, without gluing a transparent resin layer, a transparent resin layer may also be formed by using only a pressure-sensitive adhesive sheet, or only a light-hardened resin.

As described above, in this multi-layer optical disk, several layers were glued, thereby heightening its recording density. In addition, the track pitch of a row of pits or a groove which was formed in the BCA area was set to 0.24 μm or wider and 0.45 μm or narrower. Thereby, when a BCA pattern was recorded, the focus of a laser beam of light was adjusted to the metal reflection films in which the row of pits or the groove was formed, so that a suitable laser

power could be applied. Consequently, a BCA pattern could be recorded which had a low noise and a desired width.

Herein, in a ROM optical disk, the shorter its recording time becomes, the lower its costs will be. Therefore, in each of the above described examples, it is desirable that a row of pits or a groove in the BCA area and a row of pits in the main-information area be formed simultaneously. In addition, if the track pitch of a row of pits or a groove in the BCA area is largely different from the track pitch of a row of pits in the main-information area, when a master disk is manufactured, the rotational speed of the disk has to be largely changed discontinuously. Or, the main-information area is adjacent to the BCA area, and thus, the rotational speed of the disk needs to be controlled so that it becomes a desired rotational speed as fast as possible. In order to make its linear velocity constant, preferably, the track pitch of a row of pits in the main-information area should be equal to the track pitch of a row of pits or a groove in the BCA area.

Industrial Applicability

As described hereinbefore, according to the present invention, using a beam of light for reproduction having a shorter wavelength and an optical system having a higher numerical aperture, data can be recorded at a higher density

than in a DVD ROM optical disk. In addition, even though the thermal conductivity or melting point which is the intrinsic value of a metal reflection film is different, using a conventional medium-identification-information recording apparatus, medium identification information can be recorded so that an adequate defocus margin can be secured. Hence, the present invention can be suitably applied to an optical recording medium, for example, an optical disk which has a circular-plate shape and is used to generate information, or the like.